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### **Беспоисковые методы определения частоты на примере интерференционного измерителя частоты**

В данной статье будут рассмотрены беспоисковые методы определения частоты на примере интерференционного измерителя частоты, как обычного, так и более совершенного – использующего в качестве основного элемента фазовый детектор на двойном волноводном тройнике. Особое внимание будет уделено выводу зависимости выходного напряжения соответствующего интерференционного измерителя от частоты входного сигнала. Так в ходе работы будут приведены соответствующие функциональные схемы, формулы и графические зависимости.

### **Non-searching methods of frequency finding on example of the interference frequency finder**

Principally there are two main frequency finding methods: searching and non-searching.

Non-searching methods of frequency finding imply intelligence made in all sectors of working range.

Receivers (RCVs) of non-searching methods of frequency finding provide simultaneous reception of working frequencies in broad range without heterodynes and filters restructure. Frequency intelligence time during non-searching methods can be very small because all received signal components are identified together and almost instantly. For non-searching frequency finding intelligence methods with frequency discriminators, functional (interference) methods and exploration methods with multi-channel RCVs are used. [1]

Famous phase deviation from path length and frequency relation is a base for main frequency interference method finding. Intelligence RCVs

designing principal where interference method of frequency finding is used (illustrated by Fig. 1).

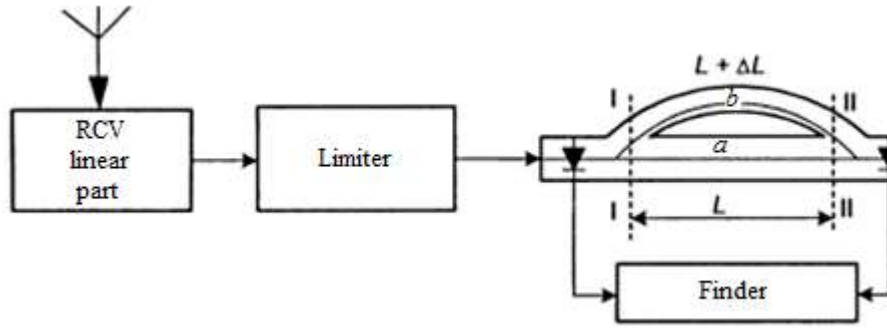


Figure 1. Interference frequency finder functional scheme

Received oscillations propagate in the common waveguide. Waveguide branches in the I-I section and signal propagates in different waveguides  $a$  and  $b$ . Waveguide  $b$  is longer than waveguide  $a$  in  $\Delta L$  value. Fields coming from  $a$  and  $b$  waveguides are summarized geometrically in the II-II section. As for summarizing fields phases they will differ in the following value:

$$\Delta\varphi = (\omega\Delta L)/v_{ph}, \quad (1)$$

where  $v_{ph}$  is an electro-magnetic wave phase velocity in the waveguide. In the I-I section (before branching) we have the following relation:

$$u_{in} = U \cos(\omega t + \varphi_0). \quad (2)$$

On the  $a$  and  $b$  waveguides outputs appropriately we have the following relations:

$$\begin{aligned} u_1 &= kU \cos(\omega(t + L/v_{ph}) + \varphi_0); \\ u_2 &= kU \cos(\omega(t + (L + \Delta L)/v_{ph}) + \varphi_0). \end{aligned} \quad (3)$$

where  $L$  is  $a$  waveguide length;  $L + \Delta L$  is  $b$  waveguide length;  $k$  is a constant coefficient.

Resulting voltage equals to (4):

$$u_{out} = u_1 + u_2 = k2U \cos((\omega\Delta L)/(2v_{ph})) \cos(\omega t + \varphi_0'), \quad (4)$$

where

$$\varphi_0' = \varphi_0 + (\omega\Delta L)/(2v_{ph}) + (\omega L)/v_{ph}. \quad (5)$$

After the second detection process the following voltage is forming on its output:

$$u_{out2} = k2U \cos((\omega\Delta L)/(2v_{ph})). \quad (6)$$

Consequently,  $u_{out2}$  output voltage is a frequency function value.

As for  $u_{out2}$  output voltage from input signal frequency relation in can be illustrated by figure 2. [2]

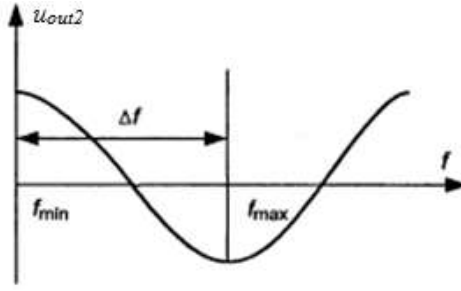


Figure. 2. Interference frequency finder output voltage from input signal frequency relation

$\Delta f$  frequency range of unambiguous frequency finding is defined by  $a$  and  $b$  waveguides lengths difference  $\Delta L$  and as it follows from (6) it can be possible only in range of any cosine semi-wave of its argument value from  $n\pi$  to  $(n+1)\pi$ . Therefore minimum and maximum intelligent frequencies are defined by the following relations:

$$f_{min} = (nv_{ph})/\Delta L, \quad (7)$$

$$f_{max} = ((n+1)v_{ph})/\Delta L, \quad (8)$$

where  $n=1,2,3,\dots$

Joint (7) and (8) solution give the following relation:

$$f_{max} = f_{min}(n+1)/n. \quad (9)$$

If  $n=1$  we can find frequency unambiguously in the following range:

$$f_{max} = 2f_{min} \quad (10)$$

$u_{out2}$  output voltage can't be used directly for frequency finding because its value depends on input signal intensity. For this dependence excluding  $u_{out2}$  output voltage to input signal normalization is made. Input signal detection is made until waveguide branching and normalizing to  $u_{out1}$  output voltage. As a result we get the following relation depending only on frequency:

$$(f) = u_{out2}/u_{out1} = K \cos((\omega \Delta L)/(2v_{ph})). \quad (11)$$

Interference frequency finder with phase detector on double waveguide branch as main element is a more perfect device that you can see in figure 3.

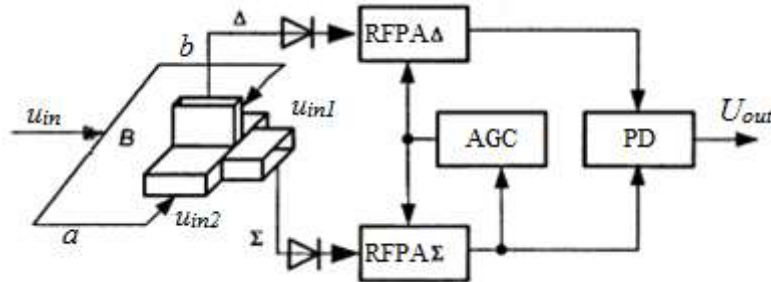


Figure 3. Interference frequency finder with phase detector on double waveguide branch functional scheme

$u_{in}$  input signal comes to  $E$  and  $H$  branches of the double waveguide branch from the antenna by the waveguide branching into  $a$  and  $b$  waveguides of different lengths in point B and then connecting to the double waveguide branch. As for  $a$  and  $b$  waveguides electrical lengths, they differ in the  $\Delta l$  value that is equivalent to their geometrical lengths difference of the  $\Delta L$  value. Then total and differential fields appropriately effect  $E$  and  $H$  branches curve detectors. From these detectors outputs signals come to the radio-frequency power amplifiers  $\text{RFPA}_{\Delta}$  and  $\text{RFPA}_{\Sigma}$  and then come to the phase detector PD.

Amplitude normalization operation is made by automatic gain control AGC scheme with the help of summarizing signal. Considering all scheme functional identity (detectors and branches matching,  $\text{RFPA}_{\Delta}$  and  $\text{RFPA}_{\Sigma}$  identity, AGC and other elements ideality) we can describe scheme work by the following relations.

Monochromatic input signal is defined as

$$u_{in} = U \cos(\omega t + \varphi_0) \quad (12)$$

Double waveguide branch  $a$  and  $b$  waveguides signals are defined as

$$\begin{aligned} u_{in1} &= U \cos(\omega t + \varphi_0 + \varphi); \\ u_{in2} &= U \cos(\omega t + \varphi_0), \end{aligned} \quad (13)$$

where

$$\varphi = (\omega \Delta L) / v_{ph}, \quad (14)$$

where

$$v_{ph} = v / \sqrt{1 - \lambda / (2a)}. \quad (15)$$

Total and differential channels input voltages are defined as

$$\begin{aligned} u_{\Sigma} &= U (\cos(\omega t + \varphi_0) + \cos(\omega t + \varphi_0 + \varphi)); \\ u_{\Delta} &= U (\cos(\omega t + \varphi_0) - \cos(\omega t + \varphi_0 + \varphi)). \end{aligned} \quad (16)$$

Therefore curve detectors and amplifiers circuits outputs are defined as

$$\begin{aligned} u_{d\Sigma} &= 2k_d K U \cos(\varphi/2); \\ u_{d\Delta} &= 2k_d K U \sin(\varphi/2), \end{aligned} \quad (17)$$

where  $k_d$  is a detectors transmission coefficient and  $K$  is the same parallel  $E$  and  $H$  branches RFPA gain.

AGC parameters should be chosen in the way that the following relation should be completed

$$K = k_0 / 2k_d \cos(\varphi/2), \quad (18)$$

and after signals multiplying in PD we have the following output voltage

$$U_{out} = k_{pd} k_0 t g(\varphi/2), \quad (19)$$

that is unambiguous connected with input signal main frequency in wide waves length range that is illustrated by the figure 4. [3]

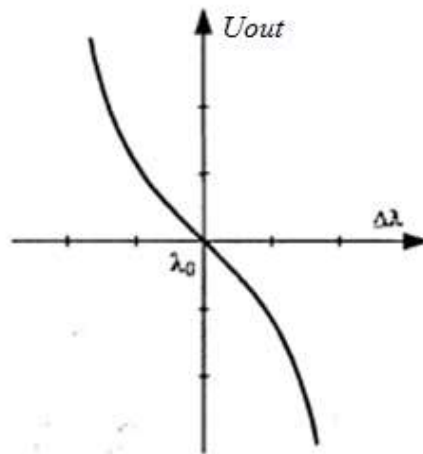


Figure 4. PD output voltage from wave length increment relation

Principally above mentioned relation can be found directly on the RFPA $_{\Delta}$  output. As for PD usage it helps to widen the frequencies range  $\Delta f$  finding by such device.

Non-searching method allows to find main frequency almost instantly but as for searching method it requires some time because of RCV resetting need. Frequency finding non-searching method allows to reduce intelligence time significantly, but such intelligence time reducing is possible because of accuracy and calculation resolution capability decreasing or devices quantity increasing. But as for searching method because of higher intelligence time it allows to find main frequency with higher accuracy and provides higher calculation resolution capability.

### Список литературы:

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